



# RESEARCH, DEVELOPMENT and TECHNOLOGY TRANSFER QUARTERLY PROGRESS REPORT (QPR)

Wisconsin Department of Transportation (WisDOT)  
DT1241 5/2014

## INSTRUCTIONS:

Research principal investigators and/or project managers should complete a quarterly progress report (QPR) for each calendar quarter during which the projects are active.

<b>WisDOT Research Program Category</b> <input type="checkbox"/> Policy Research <input checked="" type="checkbox"/> Wisconsin Highway Research Program <input type="checkbox"/> Other: _____		<b>Report Period</b> (enter year and check which quarter) Year: <u>2014</u> <input type="checkbox"/> Quarter 1 (Jan 1 – Mar 31) <input type="checkbox"/> Quarter 3 (Jul 1 – Sep 30) <input checked="" type="checkbox"/> Quarter 2 (Apr 1 – Jun 30) <input type="checkbox"/> Quarter 4 (Oct 1 – Dec 31)	
<b>Project Title</b> <u>Permeability Performance and Lateral Load for Granular Backfill behind Abutments</u>		<b>WisDOT Project ID</b> <u>0092-14-03</u>	
<b>Principal Investigator Name</b> <u>Pavana Vennapusa</u>	<b>Project Oversight Committee Chair Name</b> <u>Jeff Horsfall</u>	<b>Project Start Date (m/d/yyyy)</b> <u>8/13/2013</u>	
<b>(Area Code) Telephone Number</b> <u>515-294-2395</u>	<b>(Area Code) Telephone Number</b> <u>608-243-5993</u>	<b>Original End Date (m/d/yyyy)</b> <u>2/12/2015</u>	
<b>Email Address</b> <u>pavanv@iastate.edu</u>	<b>Email Address</b> <u>Jeffrey.Horsfall@dot.wi.gov</u>	<b>Current End Date (m/d/yyyy)</b> <u>2/12/2015</u>	

## Project Schedule Status (check one)

☒ On Schedule ☐ On Revised Schedule ☐ Ahead of Schedule ☐ Behind Schedule

## Project Budget Status

Total Project Budget	Expenditures Current Quarter	Total Expenditures	% Funds Expended	% Work Completed
\$150,000.00	\$12,734.02	\$70,643.56	47%	52%

## Project Description

The current WisDOT Bridge Manual recommends using “pervious” granular backfill behind bridge abutments to prevent lateral water pressures on the abutment walls. The granular backfill material is considered “pervious” or “free-draining” based on its grain-size distribution properties. However, the “free-draining” assumption of granular backfill does not properly consider:

- granular backfill material properties in terms of its water infiltration capacity, permeability, and water retention characteristics,
- effect of undrained water on the lateral earth pressures exerted on the abutment walls, and
- short- and long-term effectiveness of the pipe underdrain.

The specific research objectives of this work are to:

- Identify the current state of the practice of other state DOTs and scholarly articles addressing the influence of granular backfill permeability and water retention characteristics on the lateral earth pressure distribution and short- and long-term effectiveness of the pipe underdrain system, and collect relevant data for use in this research project.
- Conduct a thorough field investigation at 4 sites with structural backfill and granular grade 1 materials as selected by the project Technical Oversight Committee (TOC) to: (a) measure in situ permeability and water retention characteristics of the backfill materials, (b) measure in situ shear strength characteristics of the backfill materials, (c) monitor lateral earth pressures and pore pressures behind abutment walls, and (d) evaluate the performance of the pipe underdrain systems both in short- and long-term.
- Conduct a thorough laboratory investigation of the materials collected from the field sites and the alternative materials including recycled asphalt pavement (RAP) and foundry sand, to determine their shear strength, water retention, and permeability characteristics.

- Develop a practical quantitative approach to analyze lateral earth pressures on abutment walls accounting for water infiltration rate, pore pressure distribution due to infiltrated water flow, performance of pipe under drain, total unit weight, and shear strength characteristics of the backfill material.
- Develop recommendations specific to the current state of the practice of WisDOT's abutment granular backfill design and construction practices, and the impact of using alternative materials (RAP and foundry sand).

The project has been divided into the following five phases: (I) Literature Review, (II) Field and Laboratory Investigations, (III) Analysis and Evaluation of Field and Laboratory Testing, (IV) Evaluation of Alternative Materials, and (V) Final Report.

**Progress This Quarter** *(includes meetings, work plan status, contract status, significant progress, etc.)*

Progress has been made this quarter on Phases I, II, III, and IV of this project.

Phase I: The review of specifications from 48 U.S. state DOTs and 3 Ministries of Transportation from Canada for granular backfill has been completed. Critical parameters reviewed in backfill specifications include: gradation limits, target compaction percentage, compaction moisture control, and quality control/quality assurance (QC/QA) because they each affect the drainage and settlement properties of backfill material. A preliminary summary table was presented in the last quarterly progress report. Key findings are as follows and are summarized in Figure 1:

- 3 out of the 51 specifications reviewed required the material be placed at optimum moisture content or a percentage above (to compact material in a wet state). Currently, Wisconsin DOT specifications do not require moisture control. Recent work in the State of Iowa indicated that compacting granular material in a wet condition (by flooding) can significantly reduce the potential of post-construction collapse/settlement of compacted fill due to wetting.
- 45 out of the 51 specifications reviewed require a target compaction percentage. Currently, Wisconsin DOT specifications do not indicate a target compaction percentage.
- Even though many states have a target compaction percentage, only 16 require quality control/quality assurance in the field. Currently, Wisconsin DOT specifications do not require verification testing.
- Maximum fines content varied between 5% and 25% between specifications. Currently, WisDOT specifications require a maximum fines content of 15%.

Phases II & IV: Laboratory tests continued on the structure backfill material obtained from the SH79 bridge abutment project near Boyceville, WI. In addition, a recycled asphalt (RAP) obtained from Manatts Construction Company in Ames, Iowa was also tested as part of the Phase IV work. Lab testing involved Proctor compaction testing (ASTM D698), relative density vibratory compaction table tests (ASTM D4253&4254), and vertical permeability testing (falling head test) using large scale compaction mold permeameter fabricated at ISU. Results are discussed below.

Jeff Horsfall from Wisconsin DOT identified three bridge sites for instrumentation this Summer/Fall. These bridges include:

1. Badger Road over Branch Martin Branch in Grant County, WI
2. Hobbles Creek Road over Hobbles Creek in Price County, WI
3. Schwartz Road over Little Suamico River in Oconto County, WI

The ISU research team contact the project engineers at these sites. The projects are likely to start late July or early August and the research team will be in touch with the project engineers to setup field projects. Instrumentation required for these project sites have been acquired. The plan is to instrument each site with three pore pressure sensors (with two in the backfill and one in the creek to monitor water pressures outside the abutment) and three earth pressure cells. Tilt meters have also been acquired from the Bridge Engineering Center at ISU to monitor abutment movements associated with temperature changes.

Phase III: Analysis and Evaluation of Field and Laboratory Investigations:

Proctor and vibratory compaction table tests on structure backfill material from SH79 project are shown in Figure 2. The material showed the highest dry unit weight at 0% moisture content (oven-dried) with a bulking moisture content at about

2% using Proctor compaction method and about 4% using the vibratory method. The field moisture contents of the material were about 3 to 5%, which fall close to the bulking moisture content. This finding has consequence as materials tend to collapse/settle during any post-construction wetting, if the material is placed at bulking moisture content. Collapse tests are underway to characterize the materials' collapse potential due to wetting as a function of moisture content and dry unit weight.

A picture of the large scale compaction mold permeameter is shown in Figure 3. This setup is used instead of a standard small scale compaction mold permeameter (typically setup with 4 in. or 6 in. diameter) because the standard ones have outflow capacities lower than the outflow capacities of the testing material due to small outlet opening size and relatively less permeable porous stone. The large scale setup is specifically designed to test highly permeable granular materials with large pore size openings in the bottom of the mold. In this testing, pea gravel was placed in the bottom 6 in. of the compaction mold (which has a coefficient of permeability of  $k > 100$  cm/s). Structure backfill was placed above the pea gravel by placing a non-woven geofabric at the interface to minimize migration of fines from the backfill material. The material was placed in thin lifts at in situ moisture content (about 5%) to compact to a target 95% of maximum Proctor density. Pictures of compaction mold after sample is compacted and after permeability test are shown in Figure 4. Tests were conducted at water pressure heads ranging from 28 in. (70 cm) to 12 in. (30 cm) above the bottom of the sample at several times after the test is started. The time delay tests were performed to assess changes in  $k$  values due to clogging of the non-woven fabric material placed beneath the sample. Results are presented in Figure 5, which indicated that the  $k$  values decreased with time. The fabric beneath the sample was tested after permeability testing, which indicated that about 3.4% of the total dry weight of the material was migrated into the fabric. The field  $k$  value measured on the site was about one order of magnitude higher than in the lab – this is likely because of the higher densities measured in the lab (~93% compaction) than in the field. The material in the field was relatively loose. Additional tests are planned with tests conducted at 85% and 90% target relative compaction.

Vertical permeability tests on RAP material were also conducted (Figure 6) and the results are presented in Figure 7. The RAP material also showed a decrease in  $k$  value with time, by nearly one order of magnitude within 24 hours of the first test. Testing on the fabric material indicated that about 7.2% of the total dry weight of the material was migrated into the fabric.

The bridge abutment model fabricated at ISU is modified and prepared for testing for this project (Figure 8). Dynamic pore pressure sensors have been purchased from Geokon for instrumentation in the bridge abutment model. These sensors will be installed into the abutment model to assess pore pressure dissipation over time on different structure backfill materials obtained from the project sites. This values obtained from this model will be used to calibrate numerical analysis results using Geostudio SEEP/W.

#### **Anticipated Work Next Quarter**

The following activities are anticipated during the next quarter:

1. Continue literature review process.
2. Perform field testing at the three selected project sites.
3. Continue laboratory testing and analyze field instrumentation results.
4. Perform laboratory bridge abutment model tests using material bridge sites to calibrate numerical models.

#### **Circumstances Affecting Project or Budget**

None

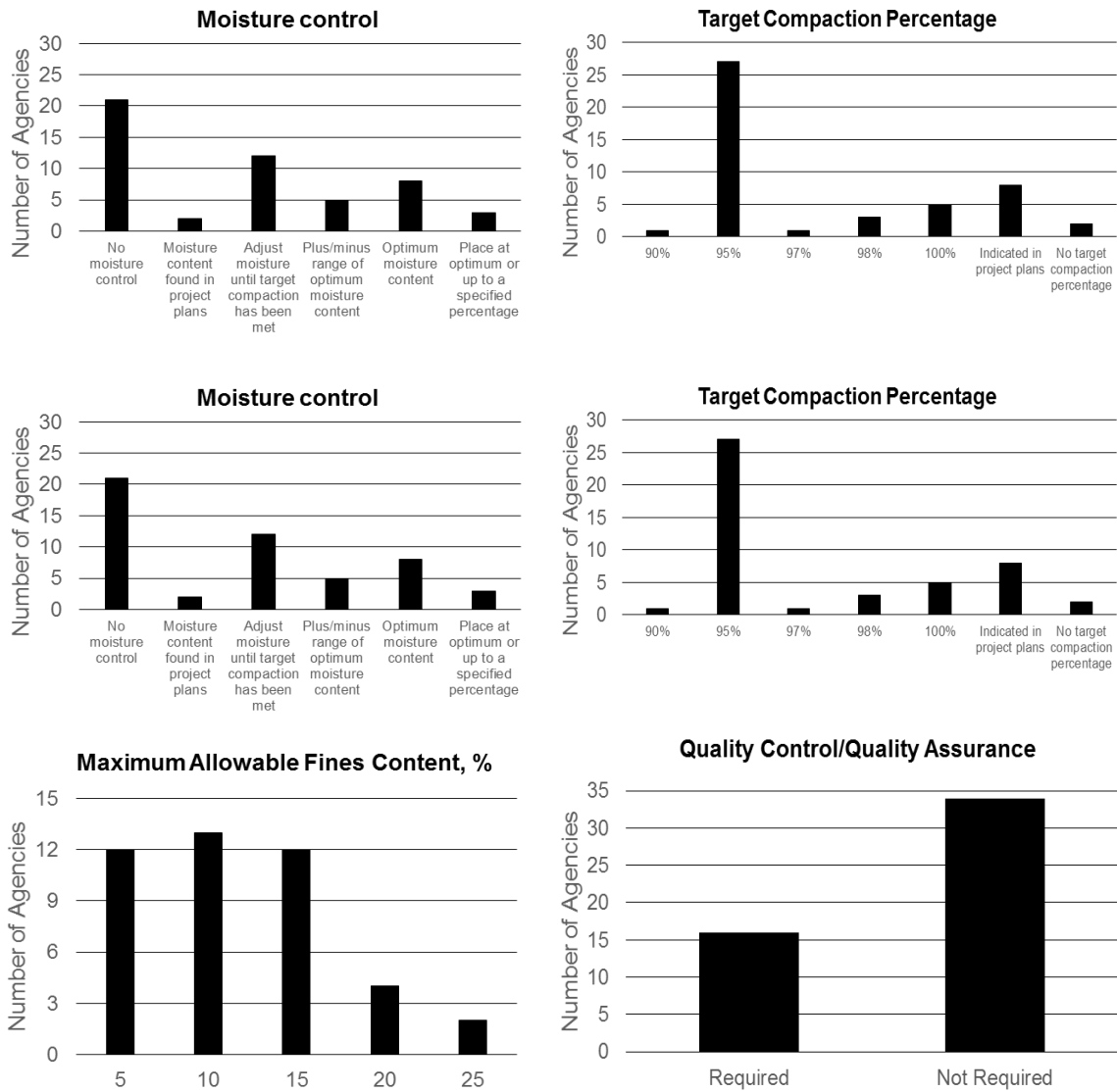


Figure 1. Results from specification review

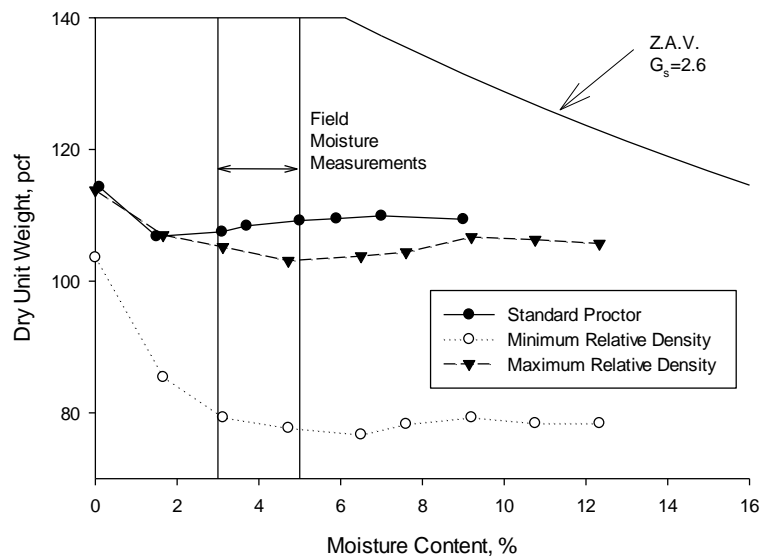


Figure 2. Proctor and vibratory table compaction test results for structure backfill obtained from SH79 bridge project in Boyceville, WI

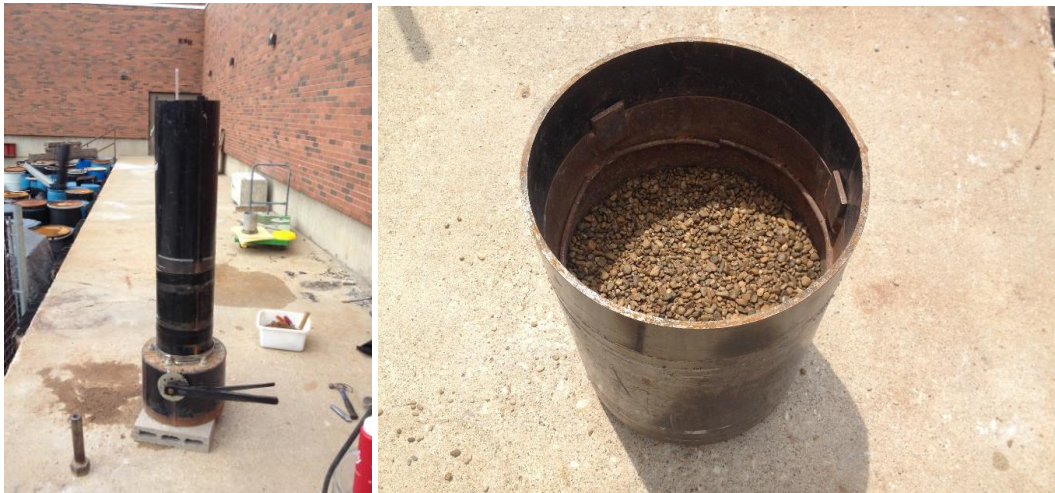


Figure 3. Vertical permeability test setup with pea gravel placed at the bottom of the sample



Figure 4. Granular backfill before (left) and after (right) vertical permeability test

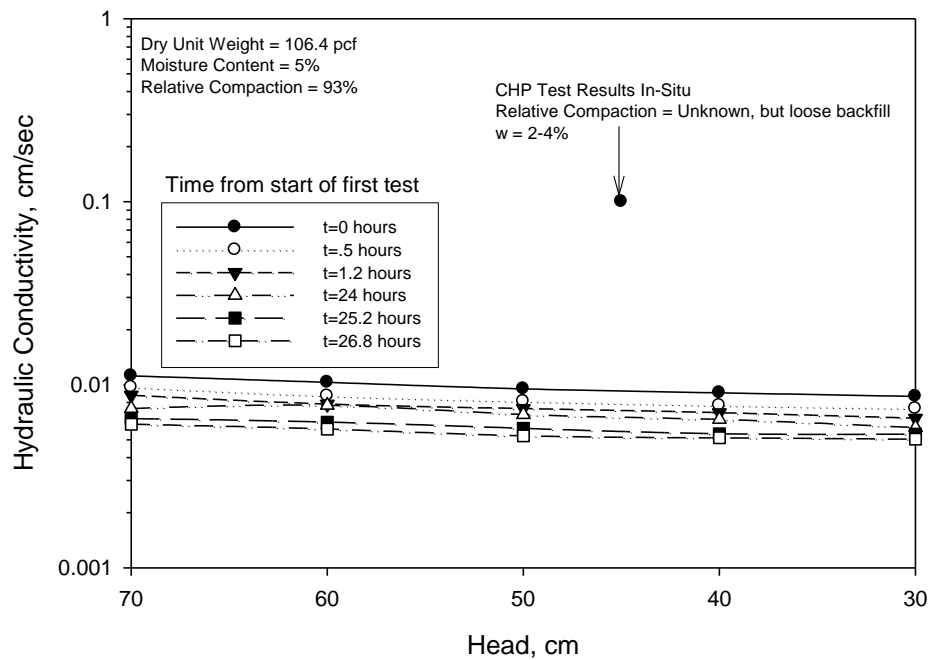
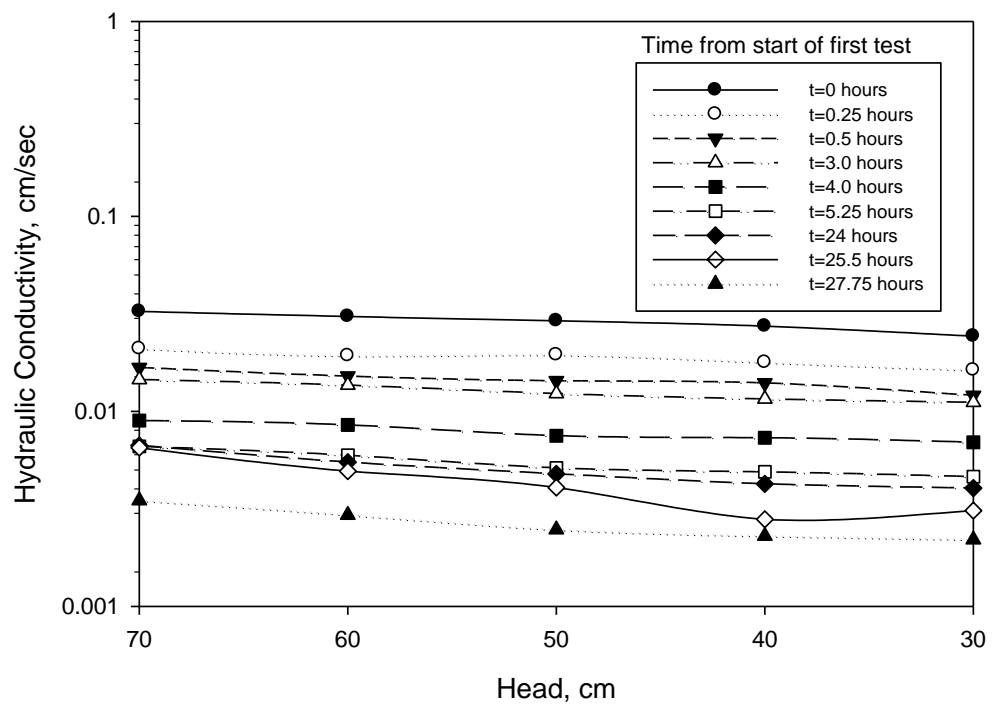


Figure 5. Vertical permeability test results for granular backfill from SH79 bridge near Boyceville, WI





**Figure 6. RAP before (right) and after (left) vertical permeability test**



**Figure 7. Vertical permeability test results for Manatts RAP**



**Figure 8. Cleaned out abutment model**

**Attach / Insert Gantt Chart and Other Project Documentation**

	MONTH																		
	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15
Phase I																			
Phase II																			
Phase III																			
Phase IV																			
Phase V																			
TOC Review, Revision, and Final Submission																			

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<b>For WisDOT Use Only</b>	
Staff Receiving QPR <a href="#">J. Walejko</a>	Date Received (m/d/yyyy) <a href="#">7/11/2014</a>
Staff Approving QPR	Date Approved (m/d/yyyy)